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Review

Can Payments for Watershed Services Help Advance Restoration of Longleaf Pine? A Critically Engaged Research Approach

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Abstract: Private forests in the southeastern US are critical for providing a variety of ecosystem services, including timber production and water resource protection. Restoration of longleaf pine (LLP) forests and savannas tends to enhance some ecosystem services, including water supply, over timber production. A variety of payments for watershed services (PWS) strategies have emerged to address the market failure associated with private forests and public water supply. The nature of these programs suggests that biodiversity protection may be a positive externality, or third-party benefit, to water resource protection. This paper uses a critically engaged research approach and expert interviews to investigate how PWS programs may help prevent land use change and promote LLP restoration. We also offer recommendations on how to sustain emerging efforts to implement PWS strategies while including LLP restoration objectives.

Keywords: longleaf pine; ecosystem services; water; forest restoration; incentive payments; critically engaged research

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1. Introduction

Strategies that protect and enhance provisioning and regulating forest ecosystem services (e.g., water supply, filtration, and attenuation) have the unique advantage of simultaneously enhancing multiple services at once (i.e., ecosystem service bundles) [1,2]. In recent decades, payments for watershed services (PWS) have emerged to address the market failures associated with private forests and clean water resources [3,4]. These programs increase the value of keeping forests as forests by offering landowners an additional stream of revenue. However, the potential of PWS strategies for advancing forest restoration overall is not well understood [5,6]. Recommended forest management scenarios, such as silviculture best management practices, are expected to have positive effects on clean water provision [7]. At the same time, management activities could also give rise to other important co-benefits, such as biodiversity preservation, which could be further leveraged through the expansion of partnerships and conservation opportunities [8,9]. In this paper, we investigate how strategic collaborations between advocates of longleaf pine (LLP) restoration and PWS programs could provide important ecosystem service bundles to diverse stakeholders and help advance forest restoration in the southeastern region of the United States.

Longleaf pine forests (*Pinus palustris*) are highly distinct biologically, and once dominated the southeastern region of the United States (US) [10]. However, changes in forest management and land use have led to considerable declines in LLP forests (less than 3% remain) and significant biodiversity loss [11]. These changes led to the North American

Coastal Plain being listed as one of 36 world biodiversity hotspots [12], supporting threatened, endangered, or endemic plant and wildlife species that depend on the LLP ecosystem, including the gopher tortoise (*Gopherus polyphemus*), red-cockaded woodpecker (*Picoides borealis*), Eastern indigo snake (*Drymarchon couperi*), Curtiss' milkweed (*Asclepias curtissii*), and *Hypericum cumulicola* [13,14]). A wide variety of stakeholder groups, including conservationists, hunters, researchers, and land managers, have expressed concern for this ecosystem, which has led to the establishment of America's Longleaf Restoration Initiative. This initiative has brought together federal and state agencies, non-governmental organizations (e.g., Longleaf Alliance, Nature Conservancy, Forest Landowners Association), and other private sector partners through an ambitious 15-year goal to increase longleaf pine acreage from 4 to 8 million acres on public and private lands by 2025. The plan also established a goal of improving another 1.5 million acres of existing longleaf acreage to meet a "maintenance" standard of fire-maintained community structure and composition [15].

Landowners are critical to the future of LLP forests since a majority of forested land in the Southeast is privately owned by individuals and families [16]. However, forest owner preferences for autonomy and avoiding opportunity costs have so far impeded widespread restoration on private forest lands [6]. Revenue generation, however, is only one aspect of landownership. It is not uncommon for forest owners to also be interested in "doing right by the land" and consider implementing sustainable forest management practices and forest restoration when feasible [7,17]. Cost-share assistance has been provided by a number of government agencies and non-governmental groups to help protect and restore forests on private lands; however, there are still challenges facing participation such as lack of awareness and general low appeal [18].

In addition to maintaining biodiversity and wildlife populations, private forests are critical for water supply, quality, and flood regulation in the Southeast. Non-industrial forest land is the primary source of water for 11 of the 13 southeastern states [19]. Most drinking water in the region is supplied by surface water, which is also important for recharging groundwater resources in fast-growing, groundwater-dependent Florida and adjacent areas of the lower Coastal Plain [20]. Unfortunately, because of their superior drainage, many of the most efficient groundwater recharge areas have already been converted from forest to agricultural and urban land uses, which tend to negatively impact water resources (e.g., pollution) [21]. Payments for forest watershed services are seen as a potential solution to relieving pressure on local water resources [22], particularly since they are seen as cost-effective and can improve landowner economic wellbeing [23].

What is not well understood is how experts and advocates of forest restoration and water resource protection see their actions and objectives as overlapping. Additionally, not well understood is how existing PWS and forest restoration incentive programs are working to engage forest owners to enhance forest ecosystem services (e.g., incentives, education). Our central research question asks: how can we merge the efforts of water resource protection groups with forest restoration advocates to help meet the broader sustainability objectives of the collective? We draw from the field of anthropology and use a critically engaged research approach to identify important overlaps in knowledge, motivation, capacity, and effort, and discuss what opportunities and challenges may be associated with advancing PWS programs and joining them with LLP restoration efforts in the southeastern US. Our findings are expected to help inform ongoing activities and add to broader conversations about payments for forest ecosystem services.

2. Approach

The critically engaged research approach seeks to highlight root causes of key issues and identify solutions, and is carried out in cooperation with advocates and stakeholders [24]. This method has been used in a variety of natural resources contexts to understand political, social, economic, and other drivers of behaviors by landowners and other stakeholders [25,26]. To our knowledge, this method has not yet been used to understand forest restoration and management in the US. A critical analysis of the LLP problem (i.e., ecological, social, and economic drivers) and of existing PWS programs in the US was conducted using a comprehensive review of the extant literature and expert interviews. Our literature search resulted in 60 publications directly related to our research question and included peer-reviewed articles, book chapters, grey literature, and for- and not-for-profit-sector reports (Appendix A). These results were synthesized and complemented with focused interviews conducted with 18 leaders in the fields of forest and watershed science, policy, and management and who work on longleaf pine and/or located in the southeastern US (Appendix B). Interviews were conducted by phone and videoconference between April and July 2020 and answers to semi-structured questions were recorded by handwritten notes. The interview data (15 pages) were analyzed by three researchers trained in qualitative date collection and analysis using an iterative process to assess the condition of existing programs in regard to: motivation of key stakeholders; program and financial design; institutional, market and technology capacity; knowledge gaps; and sustainability. In the following pages, we describe the LLP problem, present and interpret the results, and provide recommendations for advancing PWS strategies that also promote LLP restoration.

2.1. Analysis of the Problem

As coupled human–natural systems, the management of forested watersheds is often dependent on local conditions and social objectives [27]. The Southeast is the fastest growing region in the US, making private forests increasingly vulnerable to development pressure. Through 2060, the population of the Southeast is projected to grow by nearly 60% [28]. Changing market conditions and ownership patterns, including land divesture by the forest products industry and estate disposal of family tracts, have increased forest fragmentation and parcelization and altered management practices [20]. Ongoing forest loss and degradation is expected to diminish the provision of water-related services and benefits in the south [28,29]. In addition, the expanding wildland–urban interface will increase wildfire risks, dangers, and costs, and hinder prescribed burning activities. Gap analysis of the region reveals that 4 out of 7 million acres are of high biodiversity are at risk of habitat loss or degradation [30]. Private forest holdings are uniquely vulnerable to conversion as landowners seek more economically viable uses for their land (e.g., timber production, development) [6]. There is concern that the conversion of natural forests to pine plantations may negatively affect habitat quality and biodiversity values [31]. Moreover, mid-rotation intensive silviculture uses significantly more water than other common regional forest cover types [29].

2.2. Benefits of Longleaf Pine Restoration

Among forest conservation advocates, the motivation for restoring LLP forests is to protect biodiversity, but the unique characteristics of LLP can also help provide clean water services. Longleaf pine is generally considered a water-efficient tree species. In field studies, longleaf pine has exhibited stomatal control of plant water loss, resulting in rapid recovery and low mortality in response to prolonged growing season water deficits [32]. Studies also indicate that longleaf may be better adapted to drier environments relative to faster-growing slash (*Pinus elliottii*) and loblolly pine (*Pinus taeda*) [33]. At the stand level, fire-maintained longleaf savanna uses less water than other forest cover types common in the Southeast [29]. Fire-maintained longleaf stands on average used 15% less water than fire-excluded mixed pine-hardwood forests and 30% less water than intensive slash and loblolly plantations [34]. The native groundcover species associated with the longleaf pine ecosystem, such as wiregrass (*Aristida stricta*), are also efficient in their individual and community water use, relative to the woody shrubs that encroach with fire exclusion [35]. As a result of drought adaptations, longleaf stands reduce total water consumption when the availability of the resource is most limited.

These unique adaptations also mean that under higher rates of precipitation, there is more opportunity for residual water, or water yield, to flow out of longleaf pine forests compared to other forest types. Additionally, given the linkage between leaf area index (LAI) and evapotranspiration (e.g., the process by which water is transferred from the land to the atmosphere by evaporation from the soil and plants), fire-maintained LLP forests also produce higher water yield as a result of their stand structure [5]. Low density stands also require less water overall for tree growth [36]. Research has found that compared to stand structure, species of pine has a more negligible effect on water yield, although longleaf and sand pine (*Pinus clausa*) have generally higher water yields than loblolly and slash. Prescribed fire is often used to maintain low tree densities or open stand structures in LLP, but fire can also increase risk of soil erosion, until new vegetation is reestablished, and new vegetation, such as woody shrubs, may also uptake residual water [37]. Research examining these tradeoffs in southeastern forests, however, finds that low-intensity fires tend to have a moderate or short-lived effect on water yield when compared to stand structure management [38].

For practical purposes, the designation of *high* and *low* tree density values provides a coarse-grain model of possible tradeoffs between forest structure types (Table 1). Both high- and low-density forest structures are able to deliver high-quality water, and the soil erosion and water quality impacts of silvicultural treatments can be mitigated by using best management practices and restoring understory vegetation [38]. Both forest structures also help absorb rainfall and attenuate flood impacts. However, low density forests tend to have less evapotranspiration (i.e., more water yield), have lower risk of wildfire impacts, which may reduce water quality, and can help normalize stream baseflow and mitigate drought impacts compared to high density stand structures [34,39].

Table 1. Benefits and tradeoffs of low- and high-density forest structure management.

		Forest Structure	
		Low Tree Density	High Tree Density
Benefits and Tradeoffs	Water	Supply Less evapotranspiration and more water yield [5,29,34,36,38,40,41] Quality • High baseline water quality, with assumed implementation of silviculture BMPs [29,38] • Lower risk of wildfire impacts [34,39,42–44] Flow Regulation • Higher baseflows due to higher water yield [34,40,41] • Fewer low- and no-flow days [34,40] • Mitigates floods [29]	Supply More evapotranspiration and less water yield [5,29,34,36,38,40,41] Quality • High baseline water quality, with assumed implementation of silviculture BMPs [29,38] • Higher risk of wildfire impacts [34,39,42–44] Flow Regulation • Lower baseflows due to lower water yield [34,40,41] • More low- and no-flow days [34,40] • Mitigates floods [29]
	Resilience	Drought More water available for fewer trees [45,46] Insects and Pathogens Lower risk of insects and pathogens, including a secondary effect of drought [45,46] Wildfire Lower risks of severe wildfire due to lower fuel loads, including lower risk of tree mortality from drought, insects, and pathogens [34,39,42–44]	Drought Less water available for more trees [45,46] Insects and Pathogens Higher risk of insects and pathogens, including a secondary effect of drought [45,46] Wildfire Higher risks of severe wildfire due to higher fuel loads, including higher risk of tree mortality from drought, insects, and pathogens [34,39,42–44]

Table 1. *Cont.*

	Forest Structure	
Habitat and Biodiversity	Higher quality aquatic and terrestrial habitat and biodiversity values [5,40,41,47]	Lower quality aquatic and terrestrial habitat and biodiversity values [5,40,41,47]
Timber	Less fiber and timber production [6,23,48]	More fiber and timber production [6,23,48]
Carbon	Lower rate of carbon sequestration with lower risk of release due to severe wildfire [40,43]	Higher rate of carbon sequestration with higher risk of release due to severe wildfire [40,43]

Regarding sustainability, low density LLP stands are also more resilient, with superior fire, insect, disease, and drought resistance [41,43,46,49]. Long leaf pines are somewhat slower growing compared to other southern pines, which affects carbon sequestration rates, but lower risk of tree mortality also means a lower risk of accidental carbon release [6,34,44,46]. Low-density LLP forests also support significant fine-scale biodiversity and high-value terrestrial and aquatic wildlife habitat, for many petitioned, candidate, proposed, and listed species [41]. However, low-density forests also produce smaller volumes of fiber and timber, even when thinning. Harvest schedules would have to be extended to maximize economic returns on forest products, which is one reason why private forest owners tend to prefer fast growing pine species and high density stands [23].

At the watershed level, the associated water yield benefits of LLP forests are only just beginning to be understood since the restoration of LLP forests can require decades. A local study at the Ichawaynochaway Creek watershed projected a 30% increase in LLP cover could increase streamflow by nearly 10% annually and by 50% during the historically driest month [40]. Model simulations in the Altamaha River basin project that longleaf restoration, including a healthy fire regime, could have a positive impact on surface water supply while also safeguarding water quality from severe wildfire [39,42]. The first empirical, long-term, paired watershed-scale study of the watershed effects of longleaf restoration relative to intensive loblolly and mixed pine-hardwood forests is now underway at the Santee Experimental Forest unit within the Francis Marion National Forest [50].

The role of native tree species and forest structure on enhanced water provision appears promising. However, to achieve restoration benefits, management activities would need to be embedded in the broader socioeconomic context of forestry in the Southeast [51]. Skilled contractors are needed to thin stands, remove hardwoods, and plant seedlings. Mills are needed to buy and process fiber and timber. End-markets for forest products are needed to maintain forestry as an economically attractive land use. Likewise, prescribed fire may be subject to greater smoke management and air quality concerns as the wildland–urban interface expands [52]. Solutions that advance both restoration and water resource protection will need to balance these types of tradeoffs in a complex and fast-evolving terrain.

3. Drivers of Payments for Watershed Services Programs

Among the many ecosystem services payment projects, watershed services have become a major focus, with more than 387 programs in 62 countries and USD 25 billion in transaction value in 2015 [53]. Since proof of concept has been established, efforts to promote PWS are gaining traction across the Southeast. Lacroix et al. (2019) [54] outline five phases of PWS program development including scoping, management activities, decision-making, and establishing and implementing partnerships (see also [55,56]). Our interviews with experts regarding the inclusion of LLP restoration in PWS strategies revealed similar, important drivers that we discuss below: stakeholder motivation, program design, capacity among collaborators, and knowledge gaps.

3.1. Stakeholder Motivation

Among those interviewed, a common theme that consistently emerged was that utility companies would be important buyers in PWS schemes in the Southeast. Interviewees expressed that pressures on utilities come from population growth, development, and climate change, and that forests can play an important role in mitigating those impacts. They also indicated that while utilities have traditionally preferred engineered solutions to water services, many are looking for lower cost alternatives such as land conservation and stewardship (mostly private forest lands, some public lands) and other forms of "green infrastructure". It was noted that these types of buyers would also be looking for partners to help engage private landowners and share costs in establishing PWS programs. As such, management activities important to LLP restoration, such as prescribed fire, may be of interest to both water and electric utilities if it can help increase water yield and reduce wildfire risk to built infrastructure. However, utilities' motivation to support restoration will likely be influenced by whether properties are located upstream or downstream. When faced with increased costs, most utilities will impose rate-increases or charge line-item fees to customers said some interviewed. However, it is uncertain if these revenue sources could also be used to offset the additional costs of managing for LLP as a non-engineered solution for enhancing water yield or safeguarding water quality. They also speculated that utilities would be more likely to consider PWS schemes when the local government is involved in these arrangements and demonstrates support for these programs.

Interviewees gave the example that, in Florida, water management districts (WMDs) work to manage water supply and enhance flood protection through the maintenance of natural systems, which suggests that WMDs may have greater opportunity to utilize forest management for enhanced water resource protection. However, interviewees thought that most WMDs are primarily focused on recharging the Floridan aquifer as a measure of program success. Therefore, the purpose of a PWS program would likely be to support the continued authorization of consumptive use permits. Some thought that WMDs are generally less concerned if extra water rehydrates a wetland, increases streamflow, or makes a lake deeper, even though these outcomes are important to ecosystem restoration. Due to their role however, the interviewees proposed that WMDs could in theory help connect a willing payer (i.e., a utility or an applicant for a consumptive use permit) with a willing seller (i.e., a landowner). Industries with sustainable water resource goals may become initial buyers, but they would want to quantify the water yield benefit, which is still a matter of further scientific investigation. The WMDs' motivation to explore these options is likely reduced due to the administrative challenges that underpin implementation uncertainties. These challenges include structuring the PWS to meet partner needs, drafting and implementing forest management plans, establishing monitoring systems, and securing the formal buy-in of each payor. The importance of understanding payor motivations was summed up by a director of a regional conservation initiative: "In order to get them to the table, we need to know what they think the service is worth".

Those interviewed felt there was enough public support for both PWS and LLP restoration to start considering a merger in some settings. For example, much of the public has already demonstrated willingness to assume modest cost increases, as seen in the response to additional environmental fees by utilities customers. Moreover, related studies have found the public overall supports landscape-scale LLP restoration, including the use of prescribed fire (e.g., [57]). However, research also suggests that the processes or strategies used to implement these programs could give rise to differing levels of support [58]. Interviewees representing forest owners and the forest industry recommend that the strategies use to implement these programs be seen as fair and sustainable (i.e., supports responsible companies, ensures the long-term viability of natural resources), help reduce the burden on rural communities (e.g., increased landowner opportunity costs) and work to control which groups benefit from new market opportunities (i.e., fair allocation of revenues and water supply).

Interviewees were generally optimistic about forest owner willingness to participate in a PWS program, but it was also acknowledged that some owners may be cautious due to concerns about feasibility and autonomy, which may affect how incentives are received by owners. A program coordinator of a non-profit research station expressed the following concern, " . . . landowners [need to be] willing to accept some degree of oversight. Otherwise, we risk the integrity of the programs". Related research has found, however, that landowners who are early adopters of new market-based schemes also tend to have a strong sense of ethics or responsibility towards ecosystems and society [59]. Along these lines, the regional conservation initiative director discussed the importance of promoting "champions" that can help foster interest in new types of assistance programs among other forest landowners. Many forest landowners in the South are also longstanding users of prescribed fire, in many cases to improve wildlife habitat, which suggests that adding this requirement to PWS contracts would not be controversial. Related research suggests that owner participation in these programs could also help enhance the cultural ecosystem services associated with land ownership, by merging producer and stewardship roles [17,60].

In addition to direct payment schemes, those representing non-profit groups proposed that non-monetary incentives, such as sustainable forestry certifications, be used to help encourage recommended behaviors. However, an examination of the social and political dimensions of forest certification suggests this type of incentive may only be useful to owners who prioritize timber production [61]. Other types of incentives advanced by those interviewed included assisting participants with their stand management activities (e.g., stand inventory and management plans), and reducing potential costs of participation (e.g., no up-front expenditures, limit forgone timber revenues, cost-share opportunities, and considerations for economies of scale according to parcel size). Some also wanted to help owners find ways to maximize revenues in order to encourage continued forest ownership (e.g., payments for bundled ecosystem services, targeted payment levels based on slope features and forest management practices).

Interviewees also saw public engagement as a critical part of motivating stakeholders. One research scientist at a federal agency said, "We would like for people to be able to look at their neighborhoods and see what forests are providing them". Engagement often included education and outreach programs delivering information about the watershed services provided by forests (e.g., Forests to Faucets, see [62]). Social messaging and decision-making tools were used to help create common narratives for leaders in social and economic sectors as well as academics and the organizations implementing the water services programs. Activities that seek to inform professionals were also seen as important. Some of those interviewed participated in and recommended summits with potential buyers (e.g., utilities, WMDs, industry) to explore potential financing mechanisms (e.g., sales and excise taxes, bond initiatives). Those interviewed also acknowledged the need for more training for students and professionals in applied landscape conservation skills.

Since watershed issues are place-based, field building often involves a strategic assessment of potential partners. Those interviewed often participated in regional workshops that brought together diverse organizations (e.g., government agencies, utilities, landowners, nonprofit groups) to discuss ideas and opportunities. Some participants worked with regional and national partners to help build awareness and further develop a "community of practice" around PES strategies for water. The coordinator of a regional forest and watershed conservation initiative said, "Partnerships are crucial for these programs to work". Only in recent years have groups started to investigate if partnerships could be formed with water and electric utilities as well as tribal lands. A university professor of forest and water resources said, "We now have a pretty good handle on the supply side. The conversation then turns to what buyers would be willing to pay". The direction of field building efforts (e.g., bottom up, top down) varied among those interviewed. Government agencies were more often invested in decision-making tools and maps to help identify key partnerships within watersheds, whereas nonprofit groups would more often advance local collaborations among utilities, water, and soil districts and use extension services to help advance PWS solutions on private lands.

Many PWS schemes in the Southeast are still in early development, but there was some consistency in the types of collaborations that emerged. We found groups were often highly diverse in who was represented (e.g., local and regional conservation organizations, government agencies, utilities, industry, academics) and many depend on continued funding from large federal programs (e.g., EPA). In several instances, those interviewed said that partnerships with the forest industry would be a key sustaining factor, as these partnerships could help find new ways to offset impacts, help industries make smarter decisions, increase acceptability of new markets, and help link economic and ecological viability objectives. Interviewees also said that successful partnerships brought in organizations with existing programs that complement the larger strategy. For example, a program coordinator at a national conservation organization said, "We want to make sure all of our efforts are additive, not duplicative or competitive". In some cases, one partner would provide the resources or funding (e.g., utilities) and the other partners would oversee implementation and administrative activities. A few partnerships would establish a task force to identify new funding opportunities (e.g., grants, partners). Grants funds were also used to conduct market development and quantification tools. Many also looked to academic partners to help map areas of interest and quantify demand and the participation of landowners.

3.2. Program Design

Payments for watershed services programs are often categorized as user-financed, government-financed, or compliance-driven. Most of those interviewed preferred user- and government-financed options and considered compliance-driven strategies less suited for the southeastern US. Objections to compliance-driven options were supported by the already widespread adherence to voluntary best management practices (BMPs) to protect water quality during silvicultural activities [7]. Building on this, interviewees discussed the value of integrating BMPs with conserved landscapes through the use of sustainable forest certifications and conservation easement programs. One land trust in North Florida used a buy–protect–sell program to buy pine plantation land, begin to restore it, obtain an easement, and sell the land to an interested private buyer for hunting land. Those interviewed also described how payments programs could be designed to address economies of scale issues, which may interfere with expectations about voluntary compliance. For example, the Nature Conservancy and the American Forest Foundation work to pool family forest acreage to facilitate private participation in the carbon market.

Nationwide, there are a number of user- and government-financed strategies implemented by water, wastewater, and electric utilities (e.g., municipal bonds, sales tax surcharge, voluntary contributions). Research examining these programs found the types of programs that emerge are often weakly associated with how funds are generated, which suggests that financing may not be a straightforward way of obtaining certain outcomes [63]. The reason for this was explained by a staffer of a capital firm who stated, "No single entity currently benefits enough from forest health treatments to shoulder the cost of the entire program". Some proposed that watershed initiatives be used to purchase land already containing LLP (via watershed protection fees, federal endowments, and competitive grants); however, it was acknowledged that this may only work if LLP lands are already part of priority tracts. Municipal bond initiatives could also be used to buy aquifer rechange zones and open space, but without a specific focus on conserving forest lands, these bonds may not add to a strategic solution. To address the "shouldering the cost" problem, some proposed that philanthropic and industry contributions be combined to fill in the gaps and fund the protection of lands in strategic areas.

However, even when the land is secured, there is an overall need for payment designs that incorporate species composition and management techniques, such as prescribed fire. Research has found that landowner willingness to use new management techniques to enhance LLP may be largely depended on what actions owners are currently taking, and owners tend to have highly diverse objectives [64]. Since timber harvesting is not a top priority for all forest owners, some of those interviewed looked to encourage forest restoration and management on private lands by linking incentives to wildlife habitat and carbon objectives. However, the watershed scientists interviewed asserted that the need for incentives depends on the degree to which owners' current management activities already help reduce stocking density (e.g., burning, thinning, chemical treatments). In other words, stocking density should be the criteria upon which payments are made, regardless of the objective proposed by the owner. It was also proposed that instead of looking for ways to protect new tracks of lands, the properties already protected by the water management districts (including private lands under easement) could be managed for LLP restoration with support from the water utilities. The economic efficiency of managing trees for water was expressed by a representative of a regional land trust: "What is interesting is that the real-world costs of water is greater than the value of trees for pulp".

Interviewees stated that the goal of implementing innovative financing strategies and mechanisms should be to help create more stable or predictable markets. Some stated that that legislative appropriations could help manage program cash flow problems for debt services. A newer funding mechanism advanced by some was pay for success or outcomes-based financing. This model creates a revolving fund capitalized by traditional sources as well as modest levels of private investment. The approach " ... aims to crowd in multiple payers, diffuse costs and risks and promote collaboration across jurisdictions", said a staffer at an outcomes-based capital firm. Participating landowners could also be allowed to collect dividends to offset their own consumption permits. An alternative to stabilizing markets would be to have land trusts help coordinate activities and reduce administrative costs for those whose lands are important to watersheds and LLP restoration.

3.3. Capacity of Institutions, Technologies, and Markets

Those interviewed described what would likely be limits to the financial capacity of actors in PWS programs in the Southeast. Budgeting questions among investors are often limited by a poor understanding of opportunity and transaction costs. Program administrators need to weigh transaction costs with the availability of resources and expected impact on program objectives, which are often not well understood. Forest landowners also tend to have much less capacity to buffer unexpected expenses compared to larger organizations, which may lead them to be more cautious about participating. For buyers, perceptions of financial capacity are also constrained due to an improper classification of costs. "It is important to make the case for investing in upstream green infrastructure in terms that will resonate with engineers", said another representative of a regional land trust. Others go on to discuss how payments to forest landowners need to be based on the counterfactual outcome, or the additional conservation of watershed services which can be difficult to predict in some cases, such as when owners do not have a management plan. The establishment of new markets (e.g., watershed services) should also consider downstream impacts on related markets (e.g., timber, carbon), as these can have spillover effects. Though some focused on the synergistic nature of payments for multiple services, some noted the possibility of downstream economic impacts weakening the ability of partners to continue participating in PWS programs (e.g., loss of local mills).

Aside from financial challenges, the institutional capacity of key actors appears more promising, but requires significant coordination: "Field-wide conversation and coordination is needed to understand who is doing what across the landscape", said the program coordinator at a national conservation group. It was proposed that national conservation nonprofit groups help indirectly through voluntary forest management certification programs. They can also serve as intermediary groups to coordinate activities across a watershed. State agencies and WMDs often do not have the capacity to work at needed scales, but they can leverage existing capacity by building watershed forestry into their forest management plans. State agencies and WMDs are also established and trusted institutions who can serve as architects linking sellers and buyers. It was also proposed that in order to leverage existing capacities, and because watersheds have varying characteristics, payment programs should be customized to better meet the partners' capabilities and needs. It is also important to honor the developmental process and experimentation emanating from different geographies and contexts [65,66]. This said, some also acknowledged the need to foster social shifts within organizations in order to motivate changes. "As a field, we are good at solving smaller-scale conservation problems, but the collective impact approach that pulls together diverse partners is more difficult", said a representative of a regional conservation initiative.

The interviews also revealed the importance of developing new decision-making tools to help enhance the technical capacity of actors. Interviewees expressed a desire for more information about the costs and benefits of protection (e.g., the value of avoided damaged and social benefits) to refine conservation priorities and assign economic value to specific parcels. Additionally, needed are methods for oversight and verification of service provision. An example of an existing tool is the Habitat Quantification Tool to measure habitat restoration success by the Environmental Defense Fund. The Natural Resource Conservation Service (NRCS) is also working on calculators for carbon and water yield for conservation easements within Florida's Ocala-to-Osceola (O2O) corridor. Additionally needed are satellite imagery or third-party certification to ensure the agreed-upon levels of water yield and to verify management practices.

3.4. Knowledge Gaps

Those interviewed agreed that continued research in forest ecohydrology is needed to help connect restored LLP forests with watershed services. While it is understood that there can be significant gains in water supply by changing forest structure through low stocking levels and frequent fire to control hardwoods and promote a healthy herbaceous understory in the watershed, experts interviewed claim that some of the instruments used to detect evapotranspiration and interception are still somewhat crude, so it is possible some relationships exist that are too subtle to detect. Even though modeling efforts suggest that there can be water supply benefits to LLP restoration at a basin level, there are still no empirical watershed-scale studies to verify that [40,50]. Some of those interviewed were also of the opinion that it is difficult to convince water utilities, which are run by engineers and accountants, to adopt ideas specifically about forest structure and composition or about green infrastructure more generally.

Those interviewed also recognized the challenges of limited research timeframes. Many researchers will not know the ultimate results of ongoing long-term empirical studies (15–20 years) so they are calibrating hydrologic models with data about current stand and watershed conditions [50]. The calibrated models also need to work in conjunction with climate change scenarios to project future effects. Rapid turnover in timber rotations may have the potential to increase cumulative cycle water usage since water use is generally higher for younger pine stands than for mature stands, but this is still poorly understood. Many studies also demonstrate the nutrient reduction impacts of BMPs, but there is insufficient research examining the avoidance of future impacts or the results of upstream management actions on downstream conditions [67]. Interviewees from Florida discussed that while groundwater is a key resource in Florida, it is extremely difficult to model. This presents challenges in connecting buyers and sellers. This is also why much is still unknown about how to prioritize land conservation. Regional analyses of private lands tend to lose the resolution needed to make more strategic decisions; however, watershed-scale research can be costly for local municipalities.

The economic tradeoffs associated with PWS strategies are also still not well understood by those interviewed. Some claim that investors (e.g., payors) need data to understand if restoration activities could yield job creation benefits, if an outcomes-based financing model is feasible for scaling up restoration activities, and whether or not high-quality longleaf restoration will have value in the real estate market. With respect to land-use planning, policymakers want to know how much development a given watershed can support while still maintaining expected water benefits. Investors also questioned if forests should be valued more for their water quality benefits as compared to water supply services. In either scenario, economic research is also needed to help identify fair prices. Interviewees report that investors want appraisal studies prior to land acquisition to help identify the premium, both at the time of purchase and to determine future value if the long-term restoration plan is fully implemented by the private buyer. Investors also want to know how to assign an economic value to specific parcels or stands that offer multiple services. Lastly, more longitudinal studies are needed to understand the conditions under which people would continue recommended practices after the technical or financial incentives end.

At the project level, interviewees report that investors need to understand what actions will help them pass the additionality test, so they can be incorporated into negotiations. Landowners who are generally interested in prescribed fire for longleaf restoration can still have significant concerns about liability, required conditions, and cost. As such, contract design is important for both fostering greater participation and making efficient use of limited funds. Interviewees also acknowledged that the perspective of small-acreage landowners is also different than the perspective of large-acreage landowners, which also warrants investigation in the PWS setting.

3.5. Sustainability

Program sustainability depends on the ability of participants to shift effort or financial support to help maintain programming. Unexpectedly, those interviewed rarely mentioned concepts related to program sustainability, perhaps because many are still in the early phases of developing or implementing PWS programs. A few mentioned concerns about the duration and long-term effect of landowner incentive payments [68]. "Our survey found that landowners are interested in payments or cost-shares for prescribed fire—payments would help get them going with burning—but we need more longitudinal studies to understand the conditions under which people would continue the practice after the payments or cost-shares end", said a university professor of community forestry. Research examining the economic and ethical motivations of forest owners and their capacity to take action will likely be important for making predictions about the durability of forest-water suppliers under a changing market [17,69,70]. Concerns about forest owner participation were also compounded with ongoing concerns about the broader economic viability of the forestry sector in the Southeast. A lack of sufficient markets to support the financial viability of forest landownership could accelerate land-use change, reduce the availability of skilled contractors for land management, and harm local economies that rely on the forest products industry. It is unclear how new types of conservation markets may work to support or depress associated timber markets in the short- and long-term.

4. Discussion and Conclusions

Our central research question asks: how can we merge the efforts of water resource protection groups with forest restoration advocates to help meet broader sustainability objectives? To answer this, we employed a critically engaged research approach which allows the researcher(s) to be embedded in the issue, provide a subjective assessment of the problem, and make recommendations on how to address common concerns. By relying first on a comprehensive synthesis of the literature, and then on interviews with a broad range of experts, we synthesized what we thought were the most common and salient issues to advancing LLP forest restoration in the payments for watershed services space. Limitations of this study include potential gaps in the categories of stakeholders interviewed (e.g., representatives from utilities companies were not interviewed). The subjective nature of this analysis may also affect how certain issues are presented and prioritized.

We found participants in this study often had diverse perspectives regarding our question, but these differences did not suggest the presence of potential conflicts. This may be because the differences were a function of their professional roles. In fact, most showed interest in working with diverse types of partners on collaborative solutions.

We conclude that conserved lands in the Southeast are indeed not being fully leveraged through forest restoration to provide what would likely be a more valuable bundle of ecosystem services. Moreover, there are diverse categories of stakeholders and organizations that can mutually benefit from the addition of LLP restoration on PWS lands, but some have not yet combined forces. Barriers to collaboration in many cases are a lack of common understanding and vision for how conserved lands could be used, combined with a lack of clarity about expected roles within a collaborative venture. However, those interviewed stated that innovation in this area is growing and new strategies are just starting to be tested (e.g., contract design, spatial analysis tools). Efforts that seek to enhance ecosystem service bundles (versus a single category of services) may also help support diverse types of financial mechanisms (e.g., grants, markets, landowner financial assistance), but the coordination of sustainable funding sources is still wanting in many cases. In order to increase chances of overall success, pathways forward will likely need to involve the strategic cultivation of partnerships along with continuous scoping for new projects and leveraging new opportunities. Specific recommendations to this end are outlined in Section 5.

5. Recommendations

5.1. Optimize Current Data for Planning and Decision-Making

Data availability is a major bottleneck to effective program design, stakeholder engagement, and filling critical knowledge gaps. There are a number of existing datasets describing important spatial relationships within socioecological systems which can help identify hotspots for program development. Existing data include spatial data from the USDA Forest Service "Forests to Faucets" project, the forest ownership and surface drinking water supply maps produced from the Liu et al. (2020) [19] study, and the forthcoming Southeast Longleaf Ecosystem Occurrence Database from the Florida Natural Areas Inventory. To improve the technical capacity of advocates and actors, these datasets could be overlaid with Water Supply Stress Index (WaSSI) models for different climate scenarios. The Decision Support System by the Pine Integrated Network: Education, Mitigation and Adaptation (PINEMAP) project could also help identify which sites are most suitable for intensive silviculture and carbon storage and which sites are most suitable for low-density forestry and water yield management. When merging data, artificial intelligence technologies may also be useful to help address limited or incomplete information [71].

5.2. Invest in New Knowledge

Participants described a number of knowledge gaps which limit effective collaboration and exacerbate problems incumbent with policymaking and management. Partnerships with forestry, water, and conservation-focused research institutions, both within and outside of academia, can help organizations acquire research funding and support ongoing outreach and education objectives (via extension services). Research is needed to help verify water yield benefits over extended time periods, which may require the commitment of organizations that already maintain forest lands into the future (e.g., public lands, conservation areas). Technological innovation is also needed to adequately quantify water yield benefits, including additions to groundwater resources, so that they inform policy and management choices. Strategic planning and economic feasibility studies will be vitally important for encouraging public and private investment in new market strategies while also achieving restoration targets. Revenue forecasts for forest owners should include ideal planting, thinning, and harvest strategies to maximize economic while still supporting restoration objectives [6]. Research into public choice will also be important for garnering the support of local taxpayers and government officials for new types of payment schemes.

5.3. Build Out a Local Collaborator Network

There are many initiatives and spheres of activity related to PWS and/or longleaf across the Southeast that can be leveraged toward greater success in this space. For example, under America's Longleaf Restoration Initiative, as guided and implemented by the Longleaf Partnership Council, a network of seventeen Local Implementation Teams (LITs) is already strategically positioned across the longleaf pine range, working with local partners and private landowners to advance the goal of longleaf restoration in areas identified as demonstrating significant geographic importance [72]. Those teams are led by staff members of various NGOs, all pursuing the goal of collaborative landscape restoration at the local level in priority areas for longleaf restoration. Once targeted watersheds are identified, PWS efforts could be enhanced by connecting with LLP collaborators already in place. Capitalizing on this network could efficiently bring many of the other necessary collaborators to the table, including local policymakers, forest landowners, and conservation organizations.

5.4. Get Clarity on Legal Constraints

Water law in the southeastern United States largely adheres to the riparian system, wherein owners of land that borders a body of water have rights to use that water. However, laws and regulations governing water use, water quality, and water quantity can vary dramatically from state to state and even at the local level across the region [73]. These laws are also evolving as states struggle to maintain water security as competing uses stress existing water resources. For programs that use market-based strategies, it is important to consider which land and resource rights are allocated to whom and under what conditions compensation may be rendered, or restricted. An assessment of state-level water law in the Southeast could ascertain the presence of potential legal or regulatory barriers to or opportunities for the establishment of PWS programs. It is also important to assess the legality of bundling payments for watershed services with other federal and state landowner incentive and cost-share programs when programs share the same funding sources (e.g., double payment).

5.5. Get Clarity on What Motivates Collaborators and Participants

Collaborators, such as government agencies and conservation organizations, and participants, such as forest owners and utility companies, often have different motivations for engaging in a PWS/LLP restoration scheme. Proposed activities, therefore, need to be in line with ongoing investment plans or the mission of collaborating organizations. Interviewees acknowledged that in some cases, upfront work needs to be done to help key actors recognize forests as important green infrastructure and how forest management and restoration can help optimize expected benefits. Interviewees also acknowledged that collaborators tend to have different capacities and may prefer specific roles (e.g., administration, land management). Leveraging existing capacities of collaborators can help include topical experts and reduce costs. To encourage the involvement of government officials, public outreach and education about conservation markets and forest ecosystems services will also be important for cultivating awareness and support.

5.6. Clear a Path for Forest Owners

Interviewees recognized the challenges of working with diverse forest owners, and those who may be cautious about new schemes. However, motivation may be high overall if owners are be able to secure regular payments, rather than waiting for the next timber harvest rotation, and restoration activities are in line with their stewardship objectives. In this case, the barrier to participation could more often be related to the economic feasibility of managing low density stands. In some cases, owners will need access to resources to minimize transaction and operating costs (i.e., reduce up-front and sunk costs, access to qualified labor). Conservation groups and government assistance programs can also help by working together to streamline applications to existing resources. Private associations and extension services can also serve as a trusted clearinghouse for important information and training.

5.7. Design Financial Mechanisms That Fit

The development and implementation of PWS programs often require start-up and operational funding. Gauging funder interest in advance can serve as an early indicator of overall feasibility. Public and/or private grants could also play a role in scoping opportunities. Grant funds can help strengthen intermediary organizations who are working to cultivate momentum and support the development of tools for the benefit of the entire field. Having a dual focus on water resource protection and forest restoration may also expand which types of grant opportunities a program may be eligible for. Once established, mechanisms that help organizations shoulder ongoing costs together can help increase the likelihood the program will be sustained into the future, but these mechanisms should fit the needs of the partnering organizations, and the community and work within current legal and political contexts.

5.8. Develop Coalitions

As new markets come online, collaborators will gain a wide range of experiences and expertise. As these organizations take the lead, they should also form coalitions that bring together other organizations and actors who have similar interests. Greater coordination, or at least more intentional and purposeful forums for sharing experience, information, and tools, could help find synergies, and further coalesce and strengthen the combined efforts of those involved. Tools and products that could be of benefit to the broader community include feasibility assessments, outcome monitoring protocols, valuation methodologies, and public-facing materials on the watershed benefits of longleaf forests.

5.9. Pioneer New Opportunities

To build and maintain a robust network, advocates should continuously work to identify priority watersheds for source water supply protection within the historic longleaf range. This will likely involve looking to areas where there may be threats, looking for capacities within local groups and identifying champions and philanthropic groups to help generate momentum. Depending on the level of longleaf watershed research and local interest, there may be opportunities to further assess the feasibility of establishing new PWS programs with longleaf components. Similarly, if there are currently PWS programs in development within the longleaf range, it may be beneficial to establish a dialogue with those efforts and devise support strategies.

5.10. Establish Balance and Durability Goals

Consistent funding will be important for maintaining the involvement of forest owners by reducing the perceived risk of investing in new opportunities. When collaborators are asked to share program costs, it is important that these collaborations remain strong. As such, the design and approach used to establish and maintain PWS programs should be a good fit for collaborators and their policies and mission. Schemes should also be seen by local residents as promoting fair solutions and sustaining rural communities. Input–output assessments can be used to understand how investments may impact local communities, keeping in mind that conserved lands and conservation markets may affect other established markets (e.g., timber production) and the local tax base.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are available from the authors upon request.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A Literature Review Results that Informed Interviews

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Appendix B

Experts Interviewed

1. Research scientist, federal agency, 2 June 2020
2. Research scientist, federal agency, 16 June 2020
3. Program coordinator, federal agency, 12 June 2020
4. University professor of forest-water resources, 17 June 2020
5. Program coordinator, regional conservation initiative, 10 June 2020
6. Program coordinator, national conservation organization, 17 June 2020
7. Staff, outcomes-based capital firm, 24 July 2020
8. Program director, national conservation organization, 3 June 2020
9. University professor of community forestry, 17 June 2020
10. University professor of forestry, 9 June 2020
11. Conservation director, regional land trust, 15 July 2020
12. Conservation director, regional land trust, 5 June 2020
13. Consultant, watershed grant program, 9 June 2020
14. Director, payments for watershed services program, 3 June 2020
15. Program coordinator, nonprofit research station, 23 June 2020
16. Vice president, forest products firm, 18 June 2020
17. Principal, impact investment firm, 28 April 2020
18. Coordinator, regional forest and watershed conservation initiative, 16 June 2020

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